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## PREDICTING NITRIDE FUEL PERFORMANCE FOR SP-100 CONDITIONS

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### Introduction

This paper reports on the methods used to evaluate the performance of the nitride fuel design proposed for the SP-100 thermoelectric concept.

### Thermoelectric Concept

The proposed thermoelectric fuel design was for 96% dense nitride fuel clad in 0.74 mm thick PWC-11 alloy (Nb-1%Zr-0.1%C) with a 0.13 mm thick tungsten liner. The pin was to be operated at a peak cladding temperature of 1400 K, and was not vented. It would be operated at a peak power of about 13.4 kW/m to a peak burnup of 4.9 a/o. The pin diameter was 10.5 mm, with a 0.13 mm net radial gap between fuel and cladding. The pin was to be cooled by lithium.

### Analytical Approach

No satisfactory code exists to analyze the performance of nitride fuel at this time. There is a LIFE-4C code,<sup>1</sup> but the nitride aspects of the code have long been neglected. We analyzed the proposed design manually using LIFE-4C as a heat transfer code along with correlations for fuel swelling and fission gas release proposed by Brian Harbourn of the General Electric Company. The fuel swelling correlation was developed by H. Zimmerman of the Nuclear Research Center Karlsruhe (KfK) and was modified slightly by Harbourn to better correlate nitride fuel data. The fission gas release correlation was developed by Harbourn and employs the fuel temperature gradient as the primary driving force causing pore velocity and fission gas release. These correlations are the subject of a paper authored by Harbourn in this symposium.

To analyze the proposed design, we first calculated fuel temperatures for contamination of plenum gas ranging from 0 to 100%, and for volumetric swelling ranging from 0 to 9% (gap closure expected at about 8.7% V/V). Charts were prepared showing mean fuel temperature as a function of fission gas contamination with swelling as a parameter. Calculating in increments of 0.5 a/o burnup, we would assume a fuel temperature and calculate the swelling and fission gas release over all axial segments. We then determined fuel temperatures for each node and compared these with the assumed temperatures. We repeated the process until agreement was obtained between

assumed and determined temperatures at each burnup increment. Subsequently, we mechanized the procedure.

We analyzed the proposed design with this process for two cases—one case using the gas release correlation as originally proposed by Harbourn, and one case using a modified version of that correlation. The modified version used a fixed value of 5700 K/mm for the temperature gradient, a value at the high end of the data base. The modification was made to correct what we perceived to be a tendency to underpredict gas release as the correlation was originally proposed.

### Results

Axial midplane average fuel temperatures for the two cases are shown in Figure 1 as a function of burnup. Other results were as follows. For the modified version of Harbourn's correlation for fission gas release, we predicted 33% release, and 1% creep strain for PWC-11 cladding because of plenum gas pressure loading. We predicted 1.9% cladding strain because of fuel swelling. For Harbourn's original gas release correlation, we predicted 5% release and negligible creep strain for either Nb-1%Zr or PWC-11 cladding because of plenum gas pressure loading. Cladding strain caused by fuel swelling was predicted to be 1.5%.

### Conclusions

As a result of these analyses, we conclude that

1. An integrated fuel pin performance model is needed for nitride fuel pins,
2. Better understanding of fission gas release and swelling for nitride fuel is needed before detailed design of nitride fuel systems can proceed with confidence.

### Acknowledgments

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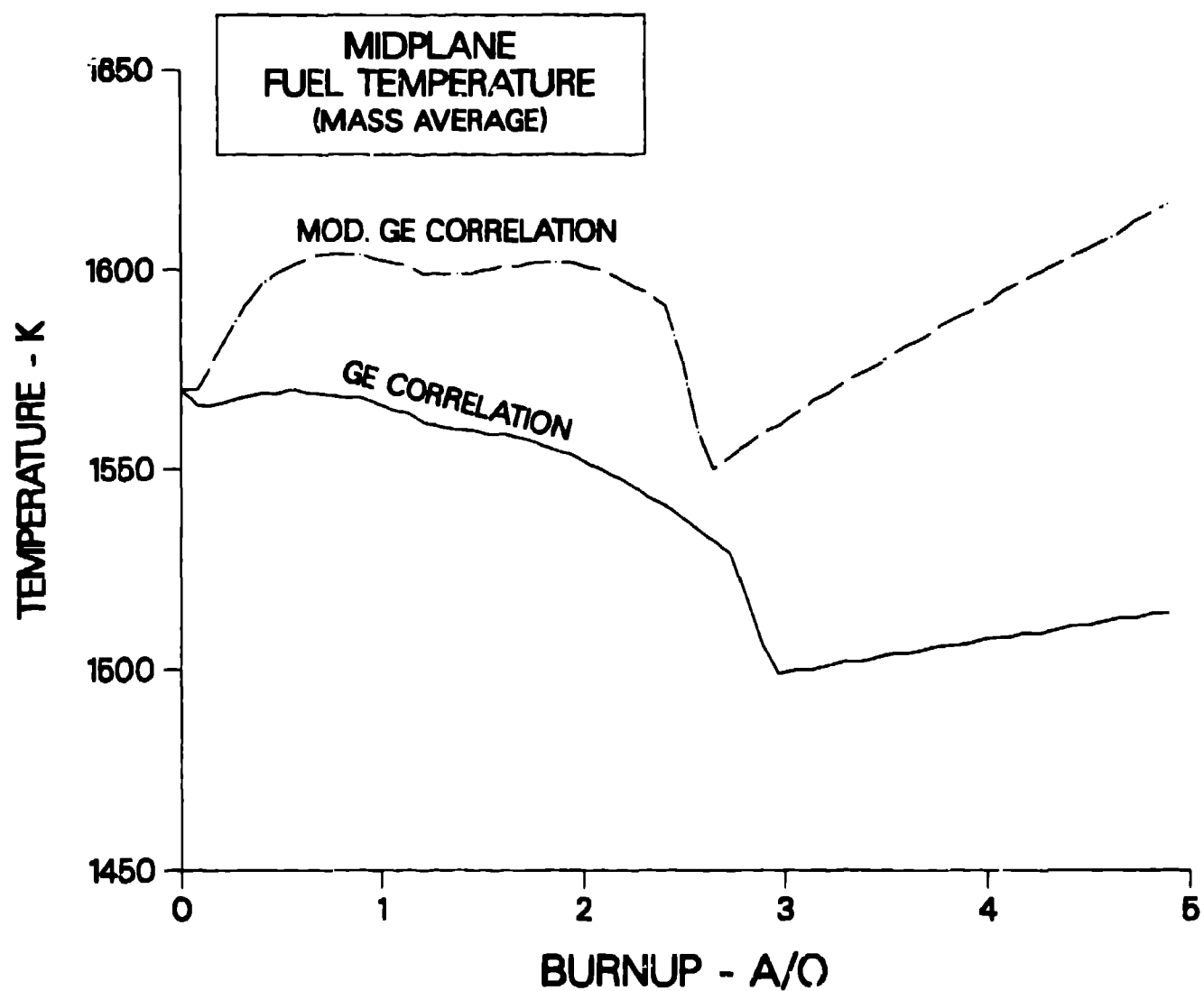


Figure 1. Mass averaged axial midplane fuel temperatures are shown for the peak powered thermoelectric nitride fuel element, both for the original fission gas release correlation provided by General Electric and for the correlation as it was modified.